THREE-DIMENSIONAL MONITORING OF MYOGRAPHIC ACTIVITY

FIELD OF THE INVENTION

The present invention relates generally to three-dimensional monitoring (e.g., measuring, imaging and displaying) of myographic activity, such as that of the uterus.

BACKGROUND OF THE INVENTION

A normal uterus does not contract vigorously throughout most of pregnancy and thus provides a tranquil environment for the growing fetus. At term, the myometrium (muscular tissue of the uterus) undergoes a series of changes that lead to synchronous, rhythmic uterine contractions, that is, labor. Contractions of the uterus are directly proportional to the underlying electrical activity of the muscle. The frequency, duration and magnitude of a uterine contraction are directly proportional respectively to the frequency, duration and propagation of action potentials in the myometrium and other muscle cells associated with movement of the uterus. (A similar situation exists in heart muscle although heart and uterine muscle are different with respect to structure and configuration of the action potentials.) Between bursts of action potentials, the uterus relaxes and recovers. The relaxation phase in uterus, although perhaps not as critical as in the heart where refilling must occur, is still very important in providing a respite for both the muscle and the fetus.

By recording uterine electrical activity, one can assess the contractility of the myometrium. It is known to record uterine myometrial electrical activity using electromyography (EMG) wherein electrodes are placed directly on the uterus. As another example, US Patent 5,776,073 to Garfield et al. describes a method and apparatus for recording uterine electrical activity from the surface of the abdomen or vagina for the purpose of diagnosing contractile patterns of the uterus or abdominal muscles in pregnant and nonpregnant patients.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved system for three-dimensional monitoring (e.g., measuring, imaging and displaying) of myographic activity, e.g., uterine activity, as is described in detail hereinbelow. The invention is described as applied to uterine activity, but the invention is not limited to uterine muscular activity and may be applied to other muscles as well.

The invention may process electromyograms (EMG), position sensing signals and cardiotocograms (CTG) to form 3D images of muscle contraction, in particular uterine

myographic activity. The invention may have many applications, such as but not limited to, prevention of premature birth, measuring and monitoring effectiveness of labor contractions, and research in obstetrics and gynecology.

There is thus provided in accordance with an embodiment of the present invention a system comprising an electromyogram (EMG) system operative to sense electromyographic activity generated in a muscle, at least one position sensor, and a processor in communication with the EMG system and the at least one position sensor, the processor operative to process data of the EMG system and three-dimensional position and orientation information from the at least one position sensor to provide an output that comprises electromyographic activity data as a function of the three-dimensional position and orientation of the at least one position sensor.

In accordance with an embodiment of the present invention the EMG system comprises at least one EMG sensor adapted to sense electromyographic activity generated in a muscle of interest and at least one reference EMG sensor adapted to sense electromyographic activity generated in a reference muscle. A monitor may be coupled to the processor, adapted to display processed information from the processor.

Further in accordance with an embodiment of the present invention a position sensing system is adapted to measure the three-dimensional position and orientation of the at least one position sensor with respect to a reference position fixed in space.

Still further in accordance with an embodiment of the present invention a cardiotocogram (CTG) monitor is in communication with the processor, the CTG monitor comprising a fetal beat-to-beat heart rate (FHR) sensor and a uterine labor activity (TOCO) sensor.

In accordance with an embodiment of the present invention the processor is operative to process data from the CTG monitor in addition to the data of the EMG system and the three-dimensional position information from the at least one position sensor to provide an output that comprises electromyographic activity data and CTG data as a function of the three-dimensional position of the at least one position sensor.

Further in accordance with an embodiment of the present invention a warning device is in communication with the processor, operative to issue a warning if processed data processed by the processor is above a predefined limit.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the appended drawings in which:

Fig. 1 is a simplified pictorial illustration of a system for three-dimensional monitoring of myographic activity, constructed and operative in accordance with an embodiment of the present invention; and

Fig. 2 is a display of an electromyogram (EMG) and cardiotocogram (CTG) displayed with a 3D image of muscle contraction as sensed by a position sensing system, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Fig. 1, which illustrates a system 10 for three-dimensional monitoring of myographic activity, constructed and operative in accordance with an embodiment of the present invention.

System 10 may comprise a CTG monitor 12. CTG monitor 12 may sense medical parameters that are important to assess the condition of a fetus, namely, fetal beat-to-beat heart rate (FHR) and uterine (or labor) activity (called TOCO), among others. Assessment of the FHR and TOCO may enable determination of the fetal condition.

CTG monitor 12 may comprise an FHR sensor 14 and a TOCO sensor 16. The FHR may be measured directly and internally, wherein FHR sensor 14 comprises a fetal scalp electrode applied to the fetal skin. Alternatively, the FHR may be measured indirectly by ultrasound, e.g., by listening to the fetal heart sound or by measuring the Doppler shift of an ultrasound wave reflected by the moving parts of the fetal heart, particularly the heart walls and/or the heart valves. For example, the FHR may be recorded by an abdominal electrocardiogram, by means of electrocardiogram electrodes or an ultrasound transducer placed on the abdomen of the mother.

TOCO sensor 16 may comprise a toco transducer (tocodynamometer), for example, placed externally on the fundus uteri of the mother, such as about centrally on the abdomen. Such a toco transducer may be a tension-measuring device, most commonly employing one or more resistive wire strains. After rupture of the membranes, an intravaginal or intrauterine toco transducer may be used, which may comprise a hose connected with a direct pressure transducer and introduced into the uterus.

A non-limiting example of a suitable CTG monitor 12 is the “HP Series 50 XM Fetal/Maternal Monitor”, commercially available from Hewlett-Packard. It monitors maternal blood pressure non-invasively, pulse oximetry, pulse rate and maternal ECG. However, the present invention is not limited by any particular technique or apparatus for sensing the FHR and TOCO.

CTG monitor 12 may be in communication with a processor 18, such as but not limited to, by means of an RS232 connection. Processor 18 may comprise, without limitation, a personal computer (PC), a dedicated processor chip or a remote processor on some website. A monitor 20 may be coupled to processor 18 for displaying processed information and images.

System 10 may comprise a position sensing system 22 that senses the three-dimensional position and orientation of one or more position sensors 24 affixed on the mother's body or the fetus. A non-limiting example of a suitable position sensing system 22 is the "PCI bird" model, commercially available from Ascension Technology Corporation, PO Box 527, Burlington, Vermont 05402, USA. The "PCI bird" measures the position and orientation of one or more receiving antenna sensors 24 with respect to a transmitting antenna 26 fixed in space. The transmitting antenna 26 may be driven by a pulsed DC signal, for example. The receiving antenna (position sensor) 24 may measure not only the transmitted magnetic field pulse but also the earth's magnetic field. Either processor 18 or a dedicated processor in position sensing system 22 may control and coordinate operation of the receiving antenna (position sensor) 24 and transmitting antenna 26, and process the signals into position and orientation outputs.

System 10 may comprise an EMG system 28 that senses electrical activity generated in a muscle, that is, electromyographic activity (e.g., electromyometrial activity of the uterine muscles). The electrical muscular activity may be sensed or monitored by one or more EMG sensors 30, which may comprise, without limitation, surface and/or needle recording electrodes. EMG system 28 may comprise, without limitation, an analog front end unit 32 in communication with an analog data acquisition unit 34. EMG system 28 is preferably in communication with processor 18.

Prior to measuring the electromyographic activity, the EMG sensors 30 may be affixed to the mother's body. A reference EMG sensor 36 (e.g., reference voltage electrode) may be affixed to a side portion of the mother's body, while the other EMG sensors 30 may be affixed to different points on and/or around the uterus.

The position sensors 24 may be placed near the EMG sensors 30 and 36, such that position sensing system 22 may measure the three-dimensional position of EMG sensors 30 and 36. Processor 18 may then process the electrical muscular activity signals as a function of their three-dimensional positions and as a function of the CTG monitor 12 readings at the same time. The processed information may be displayed on monitor 20.

System 10 may comprise a warning device 38 in communication with processor 18 that issues a warning (e.g., visual or audible) if the processed data processed by processor 18 is above a predefined limit. For example, system 10 may warn if the three-dimensional position of the EMG sensors 30 together with the TOCO information indicate the onset of premature birth. As another example, system 10 may warn if the three-dimensional position of the EMG sensors 30 together with the FHR and TOCO information indicate the fetus being in distress.

Reference is now made to Fig. 2, which illustrates an example of a display of an EMG and CTG (FHR and TOCO) displayed with a 3D image of muscle contraction as sensed by position sensing system 22, in accordance with an embodiment of the present invention. (GAL, AVIRAM - DO YOU HAVE SUCH AN IMAGE OR PICTURE THAT WOULD BE BETTER THAN MY SKETCH? IT WOULD BE NICE TO SHOW)

It is appreciated that various features of the invention which are, for clarity, described in the contexts of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination.